IPNVG fixed-focus diopter study

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ABSTRACT

Integrated Panoramic Night Vision Goggles (IPNVGs) are the prototype night vision goggles (NVGs) and may be the next generation of NVGs. The AN/AVS-9 (F-4949) NVGs, worn by Air Force aircrews, have continuously adjustable eyepieces (from +2.0 diopters (D) to -6.0 D). Unlike the F-4949s, IPNVGs have a fixed-focus eyepiece at -1.0 D. However, previous research has shown that some operators are very insistent that their visual acuity is impaired if they do not have eyepiece settings on the order -2.0 D or more, where they are currently setting their NVGs. The proposed solution is to provide "snap-on" lenses to the IPNVGs in order to obtain a selection of settings. The purpose of this study is to determine if NVGs with this discrete number (two) of "snap-on" lenses are acceptable or if additional lenses are required.

Keywords: diopter, night vision goggles (NVG), field-of-view (FOV), integrated panoramic night vision goggles (IPNVG), snap-on lens, AN/AVS-9 (F-4949)

1. INTRODUCTION

The concept of improving peoples' vision at night with image intensifier systems in the military began with the use of the starlight sighting systems used as scopes for rifles after World War II[1]. At the present time, NVGs are used by all branches of the military air and ground forces. The NVGs that are being used by the USAF aircrew and other US military aircrew are set apart from the others by the quality of the visual acuity of their NVGs. The NVGs currently being flown by the USAF are F-4949s, which have a 40-degree circular FOV. These NVGs have continuously adjustable eyepieces that range from +2.0 D to -6.0 D. At the heart of each ocular is an 18-mm diameter image intensifier tube that tube intensifies the ambient light for the aircrew member. The visual acuity achieved by the individual wearer is difficult to measure objectively and depends on numerous factors such as amount of light, weather, cleanliness of NVG lenses, and the image intensifier tube characteristics (gain, signal to noise ratio, micro-channel plate resolution, etc.). Current NVGs, under optimal lighting conditions, allow a visual acuity of around 20/25 to 20/35 (Snellen acuity). Aircrew members are always looking for ways to make flying safer and increase their situational awareness. In a survey conducted in 1992 and 1993, USAF NVG users indicated that an increased FOV was the single most desired improvement, followed very closely by increased resolution[2]. Figure 1. shows the F-4949 and the IPNVG side-by-side.

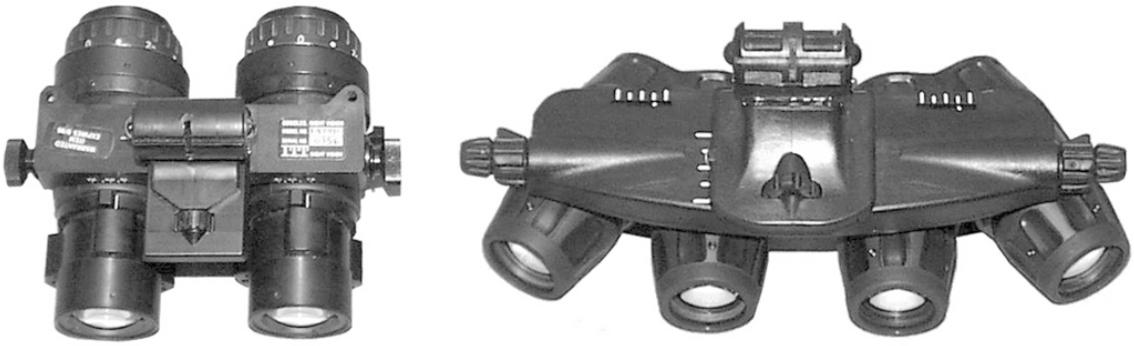

Figure 1: F-4949 and IPNVG

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The current prototype IPNVG has a 95-degree horizontal FOV and a 38-degree vertical FOV. Normally, an increase in FOV would cause a decrease in resolution, but the IPNVG doubles the number of image intensifier tubes for each ocular in order to increase FOV without causing noticeable losses in visual acuity. Several modifications to the IPNVG design offset the potential weight increase due to the increased number of image channels. For example, the image intensifier tube was reduced to 16 mm diameter and the eyepieces were fixed, thus eliminating the hardware associated with diopter adjustment. However, in order to compensate for the loss of diopter adjustment, the IPNVG eyepieces were fixed to -1.0 D and two other diopter settings (-0.25 D, and -2.0 D) were made available by providing snap-on lenses. The snap-on lenses clip over each ocular of the IPNVG. The current snap-on lenses are +0.75 D, and -1.0 D, providing the net diopter settings of -0.25 D and -2.0 D respectively. Figure 2. shows a pair of IPNVGs with a pair of snap-on lenses.

The current study was performed to see if aircrew members would find these discrete fixed-focus eyepiece settings acceptable for NVG use. The data were collected in August 2002 and were obtained from several Special Operations Squadrons in Ft. Walton Beach, Florida. The participants were special operations aircrew who routinely fly missions using NVGs.

Figure 2: IPNVG with Snap-on lens

2. METHOD

2.1 Participants

Sixty aircrew members participated in this diopter study. There were 59 males and one female. Ages ranged from 24 to 51 years with a median of 34 years. The NVG experience hours of the aircrew ranged from 20 to 3000 hours, with a median of 500 hours. All 60 aircrew completed a diopter data sheet that recorded the date, name, age, squadron, diopter settings, visual acuity (VA) set by the aircrew member, and the recorded flying diopter settings and flying VA. Forty-one of the aircrew flew with NVGs and filled out an NVG diopter data questionnaire post flight. The other 19 aircrew did not complete a post-flight questionnaire for various reasons, such as they adjusted their goggles' diopter setting just before flight, they did not wear their goggles for their part of the mission, or the flight was canceled and they did not wear their goggles. Table 1. demonstrates the aircrew position and number of aircrew participating.

Aircrew Position	Number of Aircrew	
	Acuity	NVG Questionnaire
Pilot (P)	27	17
Navigator (N)	1	1
Load Master (L)	4	1
Flight Engineer (F)	11	7
Gunner (G)	16	14
Radio Operator (R)	1	1
Total	60	41

Table 1: Number of aircrew that completed each form (acuity form and NVG questionnaire).

2.2 Apparatus
Aircrew used their own, issued F-4949 NVGs with their normal helmet-mounted battery packs. The aircrew members used the Hoffman AN/AVS-20/20 visual acuity tester, which is a device that projects a resolution chart to infinity using a collimating lens system. This device allows aircrew to adjust their NVGs to infinity on the objective lens side and to set their eyepiece focus (diopter setting) for optimum acuity and focus.

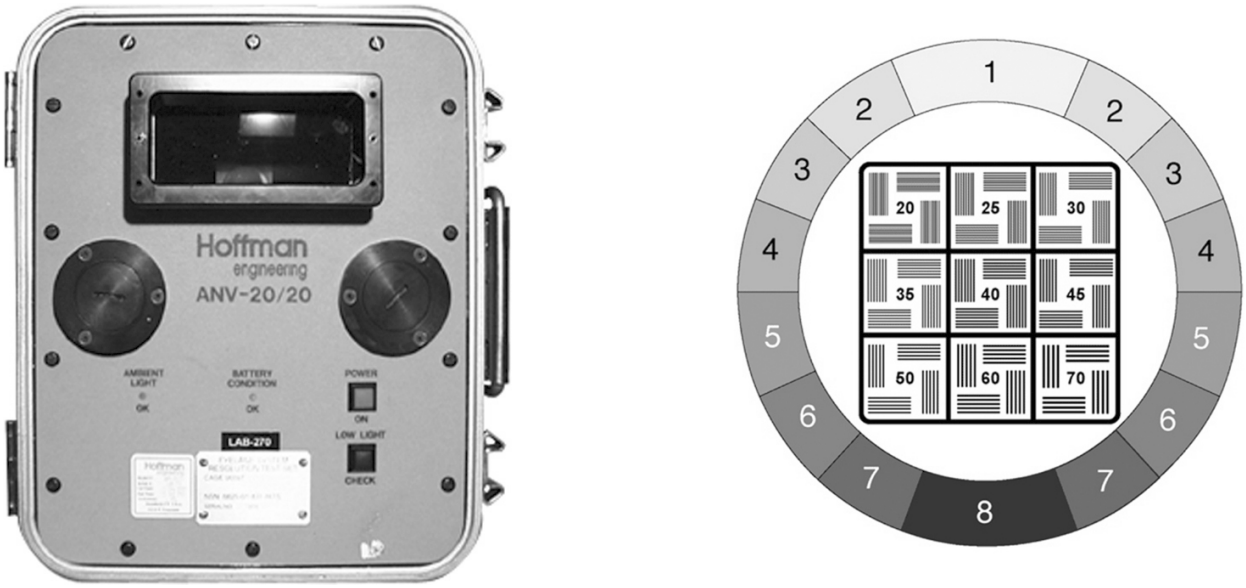

Figure 3: Hoffman ANV-20/20 and Snellen Visual Acuity Chart

2.3 Procedure
The aircrew members pre-flighted their NVGs as they normally would, first by coarsely adjusting their objective lenses while viewing into the AN/AVS-20/20. Next, they focused each ocular independently by turning the eyepiece counterclockwise (more positive diopter direction) to blur the image, and then turning the eyepiece clockwise to the least minus that brings the Snellen chart into best focus. The aircrew member repeated this for the second ocular. This procedure was repeated 2-3 times for each aircrew member depending on how close the aircrew member's settings were on the first two settings.

Based on the aircrew member's own setting, the IPNVG discrete setting that was closest to the aircrew member's own setting was then used to set the diopter value on their own F-4949 NVGs. There are 3 proposed, fixed IPNVG settings: -0.25 D, -1.0 D, and -2.0 D. If the aircrew member's ocular setting was -0.5 D or higher (less negative), then -0.25 D was selected. If the aircrew member's ocular setting was less than -0.5 D but greater than or equal to -1.50 D, then -1.0 D was selected. If the aircrew member's setting was less than -1.50 D, then -2.0 D was selected. Monocular and binocular VA were documented for all the NVG settings. If the aircrew member was able to achieve a VA that they felt was acceptable, the aircrew member flew with the pre-selected diopter settings. Figure 4. shows an aircrew member wearing a pair of helmet-mounted F-4949s.

Figure 4: F-4949 NVG

2.4 Questionnaire

When the aircrew members returned from their night sortie, they filled out a questionnaire. The questionnaire was 14 questions long. The first 5 asked background information: name, squadron, age, aircrew position, and flying hours with NVGs. The next 3 were fill-in-the blank questions to ascertain if the aircrew member did or did not adjust their eyepieces during flight: if yes, why; how long they wore the NVGs during this sortie; given a choice would the aircrew member prefer their current NVG or one with a 95-degree FOV, with a fixed eyepiece. The next 5 questions directly compared the aircrew member's own settings to when they flew with the pre-set eyepieces. The questions looked at mission accomplishment, eyestrain, blurriness, situational awareness and threat detection. The aircrew member was to circle from the choices: much worse, somewhat worse, same, somewhat better and much better. There was a comments section at the end of the questionnaire.

3. Results

Figures 5a and 5b summarize the diopter data of the aircrew members. A 'Q' at the top of a panel indicates that the aircrew member filled out a questionnaire. L and R are personally adjusted diopter settings repeated 1-3 times. • is the fixed diopter setting. Just above the replication number is the monocular visual acuity change from personal adjustment to fixed setting. * indicates binocular visual acuity was better than L or R monocular visual acuity for fixed setting, (only 14P and 55R had this). Aircrew 38P and 51P filled out acuity sheets on 2 dates, 7 days apart. Aircrew member 56P was heading out to fly and only one measurement was obtained before he went out to the aircraft.

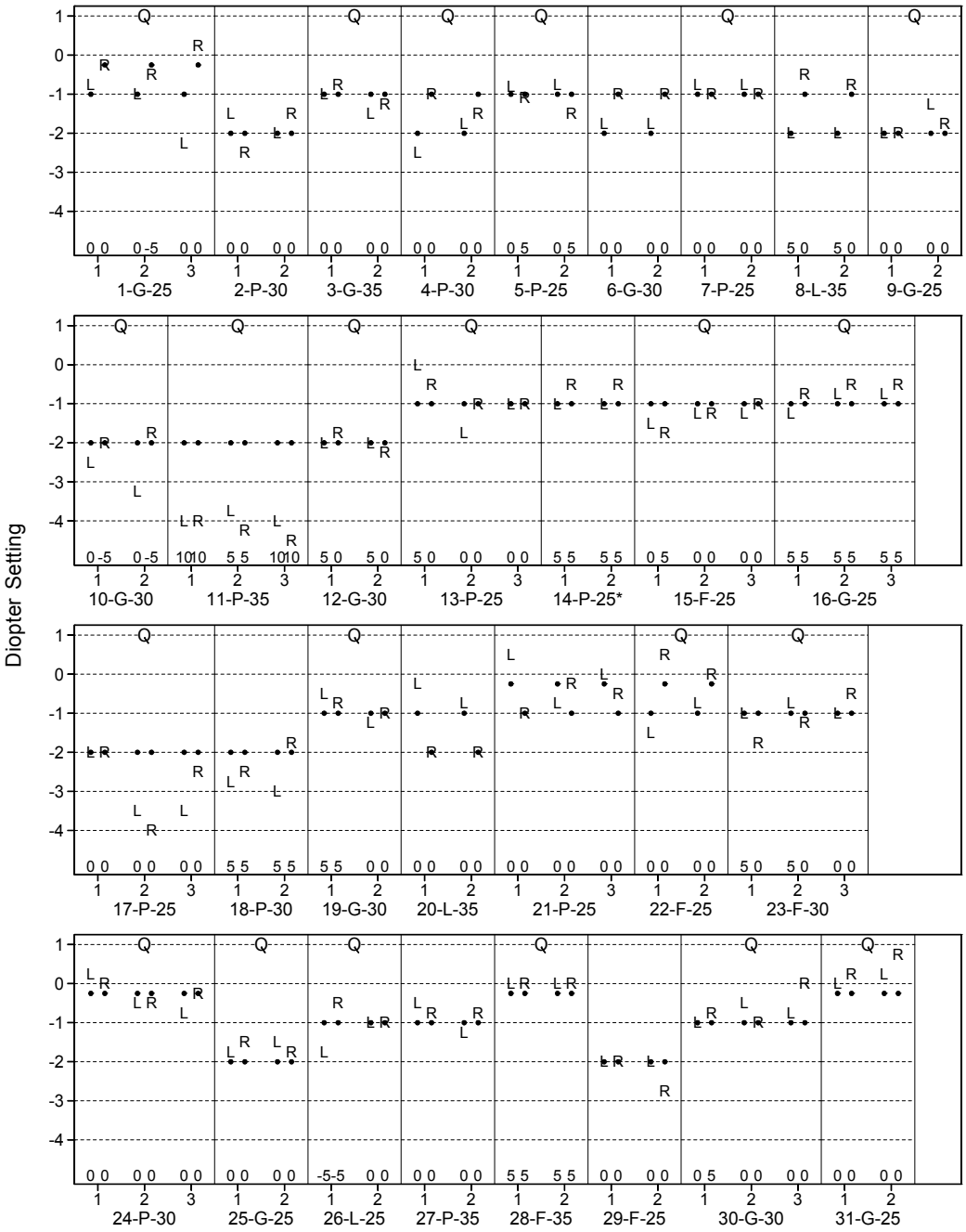

Figure 5a: Diopter settings for aircrew members 1 through 31.

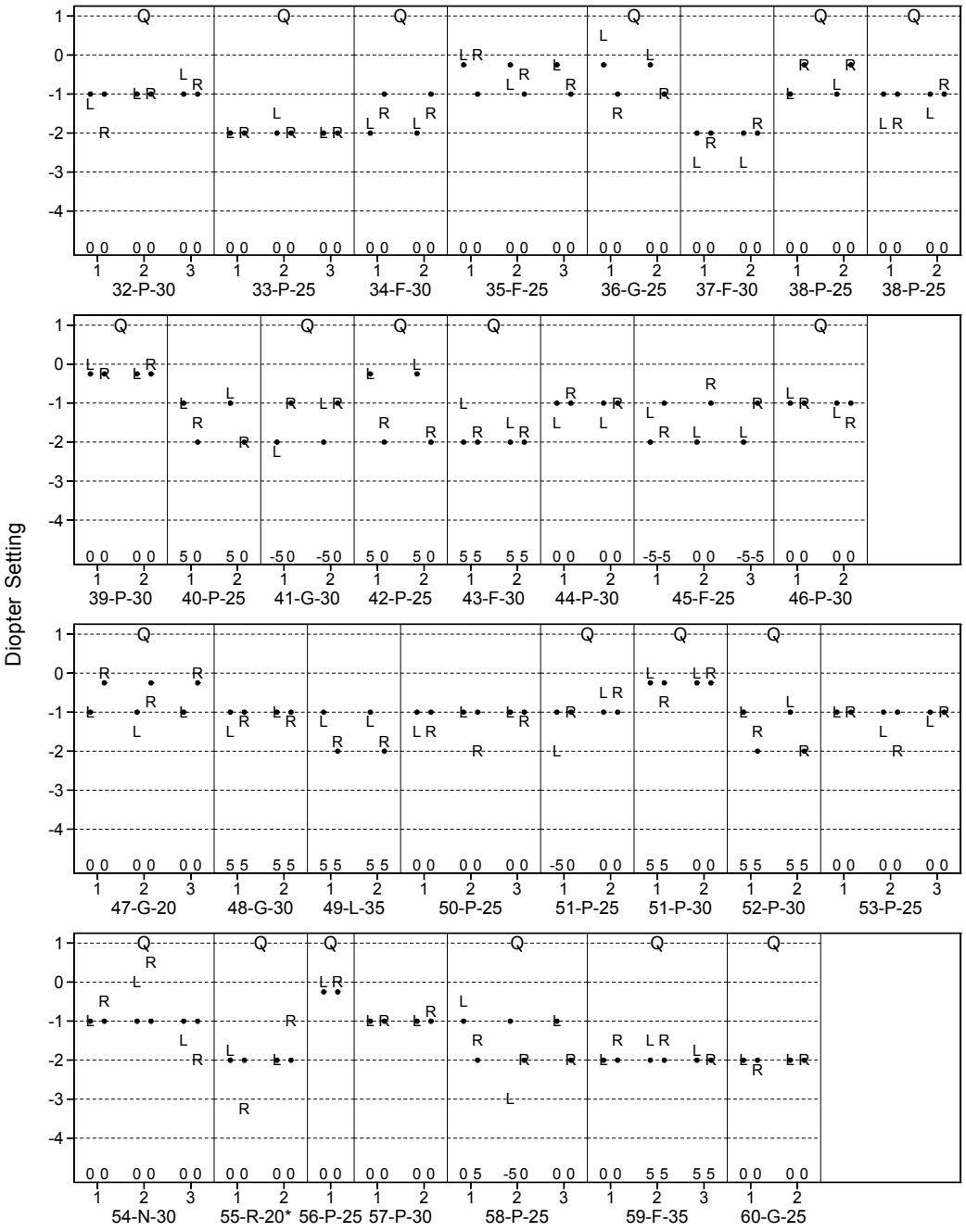

Figure 5b. Diopter settings for aircrew members 32 through 60.

A total of sixty aircrew pre-flighted their goggles. The diopter settings of 59 out of the 60 aircrew were used for estimating the Weibull distributions in Figures 6a and 6b. One aircrew member had personal setting means of left ocular -4.25 D and right ocular -3.92 D and was removed for all modeling. For a detailed explanation on the Weibull demonstration please see reference 3.

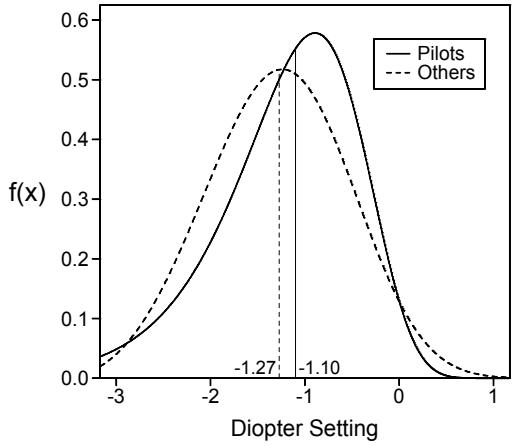

Figure 6a. Estimated Weibull distribution for pilots (N=26) and others (N=33). Referenced values are 50th percentiles.

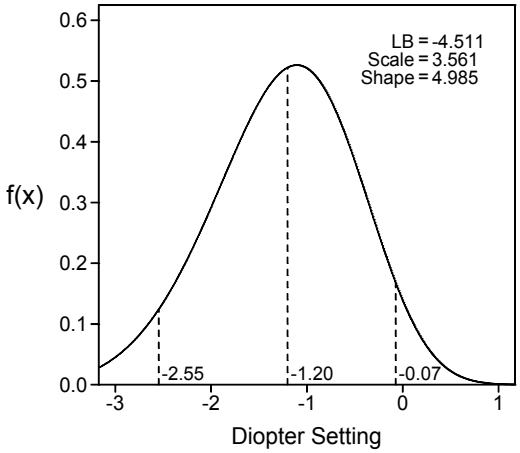

Figure 6b. Estimated Weibull distribution for 118 oculars. Referenced values are 5th, 50th, and 95th percentiles.

Nine of the 39 aircrew (23%) responding to question #9 rated the overall performance of the fixed settings to be unacceptable compared to the personal settings (aircrew # 4P, 11P, 12G, 24P, 28F, 30G, 31G, 42P, and 52P). Six of these aircrew (aircrew # 4P, 12G, 24P, 28F, 30G, and 52P) had their fixed settings within the range of their personal settings or had the average of their replications within 0.25 diopters of their fixed setting. Re-classifying these 6 aircrew as acceptable, leaves 3 aircrew (8%) having an unacceptable modified overall rating of the fixed settings as shown in Figure 7.

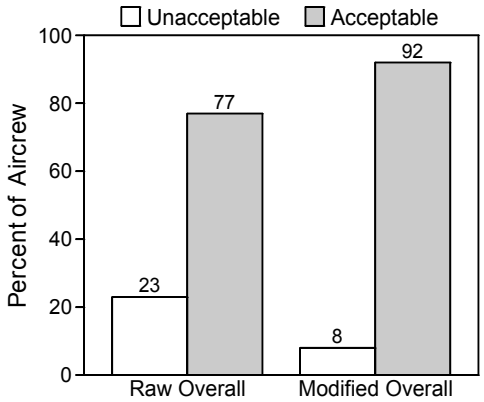

Figure 7: Percent of aircrew (N=39) indicating the overall effect of the fixed setting compared to the personal setting. Modified Overall adjusts for a close diopter setting.

For question #9, it was determined that ratings of ‘same’, ‘somewhat better’, and ‘much better’ indicate fixed diopter settings to be acceptable. If an aircrew member had their fixed diopter settings within the range of their personal diopter

settings or had the replications mean within 0.25 diopters of their fixed diopter setting, then the fixed settings were determined to be 'close' to their personal settings. Table 2 contains the frequency of aircrew by fixed setting acceptability and fixed setting 'close' to personal setting.

		Fixed Settings Acceptable		
		No	Yes	
Fixed Settings Close to Personal Settings	No	3	10	Number of Aircrew
		7.7	25.6	Percent of Aircrew
	Yes	6	20	Number of Aircrew
		15.4	51.3	Percent of Aircrew

Table 2: Percent of 39 aircrew responding to question #9 indicating a fixed setting acceptability and a closeness of the fixed diopter settings to their personal diopter settings.

4. DISCUSSION/ANALYSIS

This study was conducted to see if NVG-wearing aircrew could find a limited number of eyepiece diopter settings, as opposed to continuous adjustability, acceptable for flying. As seen in NVG diopter studies conducted in the year 2000 with the AFSOC aircrews, aircrew members were mostly setting their oculars to an average of about -1.0 D (Figures 5a and 5b). Based on the aircrew member's opinion, Figure 7 shows 77% of the aircrew found our selected IPNVG settings were acceptable for flying. Initially it appears as if 23% of the respondents preferred their own settings. However, several of the aircrew's own settings were within 0.25 D of our settings, or had self-selected settings that included our setting within their range of selected settings. These aircrew should have been able to accommodate to our settings with no problem; therefore, we reclassification these 6 aircrew (4P, 12G, 24P, 28F, 30G, and 52P) as being acceptable. With the reclassification, only 8% (11P, 31G, and 42P) of the aircrew were unable to accommodate with the three IPNVG diopter settings provided. We believe 31G may be a hyperope, 11P may have instrument myopia, and 42P may need to be re-refracted.

As shown in Figures 5a and 5b, we were able to accommodate most of the 60 aircrew members with the three possible IPNVG diopter settings of -0.25 D, -1.0 D and -2.0 D so we are going to focus on those that were less than satisfied. Number 11P may have instrument myopia[4]. He does not wear glasses and is a pilot on flying status who must pass his physical and he consistently dialed about -4.0 D into his NVG eyepieces bilaterally.

Aircrew member 31G could be considered to be unsatisfied or borderline unsatisfied, since he wanted 0 D to +0.75 D from what we were providing with the -0.25 D. His desired diopter settings in his right ocular were more positive than what we were providing; he may be a latent hyperope. However, he showed no decrement in VA with the bilateral eyepiece settings of -0.25 provided.

Aircrew member 42P had an acceptable VA, but he had an imbalance almost 2.0 D between his right and left eyepiece setting. He may need to see an optometrist to be refracted. One would expect that he has been inducing significant eyestrain and fatigue. Aircrew member 58P also had acceptable VA and had about 1.0 D disparity between the oculars; he, too, has likely been inducing eyestrain. Prior research has shown that an optical instrument user's eyes do not accommodate appropriately to stimuli with a greater than 0.5 D difference between the oculars[5].

Aircrew member 12G had selected diopter settings that were identical to our settings for his left ocular (twice), and had selected right ocular diopter settings that were within 0.25 D from our diopter settings. What was interesting was that he preferred his own setting to our settings. Aircrew members often like to control as much of their flying environment as possible. In this instance it appears that there was a control issue. Aircrew members 24P, 28F, 30G, and 52P all had their own average settings within 0.25 D of the fixed-focus setting and it was expected that they should have found the fixed-focus settings acceptable and there was likely a control issue with these aircrew as well. These control issues can be overcome by training.

Aircrew member 10G is a good example of why having a fixed-focus eyepiece can be beneficial to aircrew members. His own settings had over 0.75 D difference in his left eye from one trial to the next, and he actually preferred the fixed focus setting to his own. He was dialing in more negative power than he actually needed, so we decreased his eyestrain by providing him the -2.0 D fixed-focus for both eyepieces, eliminating the disparity between his eyes.

Table 2 looks at the aircrew's feedback, the aircrew member's diopter setting and the chosen fixed-focus setting and groups them into categories. The group of particular interest that has not been discussed to this point are the 10 aircrew members who had chosen eyepiece settings farther than 0.25 D from their own settings, but found the fixed-focus settings acceptable. Aircrew members: 5P, 10G, 15F, 16G, 22F, 25G, 34F, 36G, 38P, and 43F are included in this group. This group was able to accommodate the fixed-focus settings more than 0.25 D from their own settings. For 10G, the fixed-focus settings probably helped him, since his VA improved with the fixed-focus settings. The reporting of VA information is clearly subjective; 10G had the same self-selected and fixed-focus setting for his first trial of his right eye, yet he reported improved VA with the fixed-focus setting. It is possible that NVG positioning may have had some impact. Each time the aircrew member snaps the NVG to his helmet, it will be in a slightly different position. The disparity between his left and right eyepiece settings was removed with the fixed-focus settings.

5. CONCLUSION

Is it possible to satisfy the needs of the majority of aircrew members wearing NVGs with three fixed diopter settings? The answer appears to be yes, with the appropriate selection of diopter settings. In a previous AFRL NVG study with some statistical modeling of the collected field data , it was found that a range from -0.25 D to -2.25 D would cover about 75% of NVG wearing aircrew[6]. In our current study fixed settings at -0.25 D, -1.0 D, and -2.0 D, were able to satisfy 92% of the aircrew.

Assuming people can accommodate 0.25 D, aircrew whose own settings fall within 0 D to -2.25 D should find the three discrete diopter settings acceptable. Aircrew with settings outside of this range should be examined to determine why their settings fall outside of the norm.

VA as measured by using the Hoffman 20/20 is a subjective assessment, as is our question asking the aircrew members which setting they preferred. There was at least one member, 12G, who had identical settings to our settings for his left ocular and our diopter setting fell in the middle of his two chosen diopter settings for his right ocular. It was expected that he should have found no difference between his and our settings, but he responded that our setting was unacceptable. This perceived loss of control is an area that will need to be addressed. Aircrew members need to feel comfortable with the settings that will be available to them.

For some individuals, like 11P, night or instrument myopia may be the cause of their fit problem. Past literature has shown that many subjects are unable to relax accommodation when using optical devices[7]. It is possible that this aircrew member and others like him could benefit from optical training from an optometrist, to teach his eyes to accommodate appropriately.

Others, like 42P and 58P, who both had greater than 0.5 D ocular disparity, could have been suffering eyestrain. They could possibly benefit from a refresher course in NVG diopter settings. Of course, one of the benefits of having a fixed focus ocular is that aircrew will be encouraged to fly with a matched set of eyepieces. Additionally aircrew who can tolerate the -1.0 D fixed-focus oculars have the added benefits of a lighter NVG than those flying with the helper-snap-on lenses.

Future field NVG diopter studies could examine the acceptability of discrete settings based on the aircrew member's choice of setting, but with a matched setting, like -2.0 D. This should discourage eyestrain caused by having ocular disparities from mismatched diopter settings. Of course for individuals that could not be accommodated with one of the above solutions, custom fit snap-on lenses could be used.

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BRIEF BIOGRAPHY

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